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Progress Report No. 5

RESEARCH PROGRAM TO DEVELOP A TECHNOLOGY IMPROVEMENT PROGRAM FOR CLOSED DIE FORGING

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Activities During Month of December 1965

During this period, a number of forging tests were conducted. These tests were up-set forging tests on 7075 aluminum forged between flat dies. The material was in two sizes, 2" in diameter by 1.5" long (volume 4.712 cu. in.) and 2.5" in diameter by 1" long (volume 4.910 cu. in.). In all cases, these slugs were heated to 800°F. Four slugs were forged for each test condition. Two of these (odd numbered samples) were of the 2" diameter size and two (even numbered samples) were of the 2-1/2" diameter size.

The forging was done on a 500-ton press in which the hydraulic pressure was controlled to produce a range of disc thicknesses. The pressures used ranged from a low of 296 psi, generating a total load of 67 tons on the ram, to 2500 psi, generating a load of 565 tons. This, over the die temperature range used, produced forged biscuits from .128" minimum to .688" maximum thickness.

The dies were heated in a furnace immediately adjacent to the press and transferred to the press, locked in position and ready for forging in a matter of 3 to 4 minutes. They were heated to the maximum temperature required for the run with an over-allowance of 25 - 50° to take care of the drop during transfer. This drop was generally in the neighborhood of 10 - 15 degrees. Lower forging temperature ranges were obtained by allowing the dies to cool in the press between groups of samples. The temperature of the dies were continuously monitored through thermocouples placed in wells 1/2' below the working face of each die. This permitted a determination of the average top and bottom die at the time of forging each sample.

The die temperatures in these tests ranged from a high of 820° F to a low of 395° F. The time required for forging each sample was approximately 20 to 25 seconds. During the forging, the dies cooled some 10 to 15° F between samples for the 550 - 650° F level; and less than 5° F for temperatures of 450° F and below. This cooling was generally quite regular for the higher temperature but at the low temperature the abrupt change in the slope of the cooling curve demonstrated that the dies were picking up heat from the 800° F slugs. This was quite apparent and had the test been extended to a large number of slugs instead of the four slugs used, an increase of die temperature would have resulted. In these tests, however, the small slug mass compared to the large mass of the dies and the use of a limit of four slugs in each condition simply reduced the cooling rate of the die.

The lubricant used for these tests was an oil based graphite containing some lead compound; it was applied as spray after dilution with kerosene. This lubricant was sprayed on the dies prior to heating and just before the forging of each sample. The working surfaces of the dies were placed together during the heating so that they and the initial lubricant coating were protected from excessive oxidation in the furnace. Spraying of the lubricant as previously reported, and in agreement with previous experience in our own forging shop and also noted by others, is the most efficient method of application. The kerosene, however, produces clouds of fog which is quite a nuisance and required extensive ventilation. In normal forging operations, the fog is largely prevented by ignition by die heating burners which were not used in these tests. It should be noted in passing that the extensive ventilation required to dissipate the fog contributed to rapid die cooling.

At the higher die temperatures, the rapid vaporization of the spray tended to keep the lubricant from sticking to the die surface and contributed to the scatter of results. At the lower temperature (400 - 500° F) the lubricant adhered to the surfaces much better and the data showed significantly less scatter. It is apparent that when the much higher die temperatures contemplated for titanium and maraging steel are used, some improved method of applying the lubricant will be required.

The data logged for each sample included the following:

1. sample number and size
2. forging stock temperature
3. die temperature - top and bottom
4. hydraulic pressure
5. forged disc thickness
6. forged disc area
7. unit load applied

These data are tabulated in the attached sheets which also include a chart of unit load in tons per square inch plotted against forged disc thickness. In these tables the forged sample thicknesses are averages of the mininum and maximum readings on each. The maximum range of thickness variation on the samples was approximately ±.010" with an average range ±.005". Most of this variation is believed to come from variable compression of the insulating material inserted between the dies and the holders to reduce loss of heat to the press and prevent excessive heating of the press parts. Normal clearances in the press guides and factors related to die placement account for the rest.

The area of the forged samples was determined from the initial slug volume and the thickness of the disc. Unit loads on the sample are based on the area of the forged sample. The press load was calculated from the hydraulic pressure used and the ram area of 452 sq. in. It is expressed in tons per square inch of forged sample area.

The data from these tests are summarized in the accompanying chart of unit load plotted against forged sample thickness. The unit-load thickness relationship indicated by this chart is in general agreement with expected trends. However, the difference in load with change of die temperature is somewhat less than that expected and the scatter of the data is greater than anticipated.

For the purpose of presenting the differences that the data illustrate, the curves are drawn through the minimum points and indicate the minimum unit loads observed for the thickness ranges obtained in each temperature range. Curves drawn through the averages of each temperature group or through maximum points would produce a meaningless overlap of curves. Curves through the minimum allow definite differences to be observed as die temperature changes although these differences beyond 650° F are less than anticipated. Larger starting samples involving greater metal volume, larger surfaces and more metal movement would be expected to produce greater differences. Larger samples would, however, be much more costly, require larger dies and the use of a larger press.

The curve for the die temperature range 700 - 750° F differs from the others in that it is arbitrarily placed. Its points approximate the same position as the curve for the higher temperature (750 - 810° F) range. At the present time, this is not understood, nor quite believed. Additional tests will be necessary to establish its position. For the present, it is placed approximately between the curves for the higher and lower temperatures. The data points are nevertheless plotted as required by the results to date. This curve should, however, not be given much weight in any analytical consideration of the data and it should be kept in mind that it is quite probable that no distinction can be made between these temperature ranges. It is hoped that additional tests will reduce the scatter pattern and allow more certain placement of these curves. Current plans contemplate additional tests which will further define the shape of these curves, particularly at the lower thickness values.

The data from these forging tests is preliminary in character and insufficient in quantity to permit drawing of definite conclusions. Additional tests planned for the immediate future are expected to provide further information and allow more specific interpretations. Cursory examination of the tabulated data and charts, however, do present some tentative information. For the forging conditions so far used in these tests, it would appear that the unit forging loads are influenced most by die temperatures above 650° F for thicknesses less than about .300 inch and particularly for the range of .125" to .200". At the lower thicknesses the unit load rises steeply for all die temperatures utilized, as may be expected, but it is apparent that thinner discs can be produced at the 750 - 820° F die temperature than at 600 - 450° F and that the unit loads will also be significantly lower. The data are insufficient to indicate the limits that can be approached but it is quite evident that they are significantly influenced by die temperature. Subsequent test work is expected to provide more definite indication. At the higher thickness ranges, it is apparent that die temperatures do not greatly influence the unit loads required.

Although the forging of 7075 aluminum alloy is a definite part of this project, the primary interest is centered on the forging of maraging steel and the 8-1-1 titanium alloy. Some of that forging is planned for the near future. However, the ready forgeability of aluminum and the ease of handling because of the lower temperature involved makes the aluminum forging of great value in working out the test details and refining techniques prior to undertaking the more difficultly forged materials. Much of the information obtained in the work with aluminum is expected to be transferable to the other metals and help that work go more smoothly and surely.

In addition to the above activities, machine work on the other die parts has been under way and has reached the following status:

1. Inconel 713 C parts for flat die work have been received and machine work begun.
2. Hardtem parts for the cupping die have been machined and are being readied for initial forging tests.
3. Inconel 713 C parts for cupping die have been received and machine work scheduled.
4. Machining of forging slugs for both flat and cupping die test are on schedule.

Work programmed for January is as follows:

1. Machine work on 713 C die parts.

2. Additional forging of aluminum slugs on flat dies to fill gaps in present data and refine technique.

3. Tryout tests of Hardtem cupping die parts.

TABLE I - Test No. 5 data

Test No.	Sample No.	Stock Temp. °F.	Die Temp. °F.	Pressure Psi	Thickness Inches	Area Sq. in.	Unit Load T/sq. in.
5-1	1	800	750	2180	.162	29.1	17.0
	2	800	735	2180	.145	33.9	14.6
	3	800	725	2150	.140	33.7	14.4
	4	800	715	2180	.142	34.6	14.3
5-2	5	800	615	2150	.154	30.6	15.9
	6	800	610	2150	.153	32.1	15.1
	7	800	610	2220	.154	30.6	16.4
	8	800	605	2220	.160	30.7	16.4
5-3	9	800	505	2220	.170	27.7	18.1
	10	800	505	2220	.170	28.9	17.4
	11	800	505	2220	.183	25.7	19.5
	12	800	505	2220	.188	26.1	19.2

TABLE III - Test No. 7 Data

Test No.	Sample No.	Stock Temp. °F.	Die Temp. °F.	Pressure Psi	Thickness Inches	Area Sq. In.	Unit Load T/sq. in.
7-1	1	800	735	1340	.165	28.6	10.5
	2	800	730	1388	.172	28.5	11.0
	3	800	725	1340	.176	26.8	11.3
	4	800	720	1360	.173	28.4	10.8
7-2	5	800	630	1360	.227	21.2	14.5
	6	800	625	1360	.185	26.5	11.6
	7	800	620	1360	.188	25.1	12.3
	8	800	615	1340	.193	25.4	11.9
7-3	9	800	535	1340	.220	21.4	14.2
	10	800	535	1310	.236	20.8	14.2
	11	800	525	1340	.221	21.3	14.2
	12	800	525	1310	.232	21.2	14.0

TABLE IV - Test No. 8 Data

Test No.	Sample No.	Stock Temp. °F.	Die Temp. °F.	Pressure Psi	Thickness Inches	Area Sq. in.	Unit Load T/sq. in.
8-1	1	800	820	2500	.128	36.8	15.4
	2	800	815	2500	.141	34.8	16.2
	3	800	810	2500	.133	35.4	15.9
	4	800	800	2500	.135	36.4	15.5
8-2	5	800	420	2500	.167	28.2	20.0
	6	800	420	2500	.180	27.3	20.7
	7	800	420	2500	.180	26.2	21.5
	8	800	420	2500	.175	28.1	20.1

TABLE V - Test No. 9 Data

Test No.	Sample No.	Stock Temp. °F.	Die Temp. °F.	Pressure Psi	Thickness Inches	Area Sq. in.	Unit Load T/sq. in.
9-1	1	800	805	1000	.200	23.6	9.6
	2	800	800	1070	.196	25.1	9.3
	3	800	790	1000	.207	22.8	9.9
	4	800	780	1000	.217	22.6	10.0
9-2	5	800	430	935	.274	17.2	12.2
	6	800	425	975	.265	18.5	11.9
	7	800	420	900	.271	17.4	11.7
	8	800	415	935	.275	17.9	11.8

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